Total Maximum Daily Load (TMDL)

for

The Bayou Caddy Watershed

In the Coastal Streams Basin of Mississippi

To address Impairment due to Nutrients

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In compliance with the provisions of the Federal Clean Water Act, 33 U.S.C. § 1251 et. seq., as amended by the Water Quality Act of 1987, P.L. 400-4, the U.S Environmental Protection Agency (EPA) is hereby establishing Total Maximum Daily Loads (TMDLs) for total nitrogen and total phosphorus for Bayou Caddy in the Mississippi Coastal Basin. Subsequent actions must be consistent with these TMDLs.

As with all TMDLs, the State or EPA in coordination with the State, has the authority and prerogative to revise or totally rewrite these TMDLs if new information becomes available that warrants such action.

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James D. Giattina Date
Director
Water Management Division

FOREWORD

The TMDLs in this document are being established pursuant to the U.S. Environmental Protection Agency (EPA) commitments in the 1998 Consent Decree in the Mississippi TMDL lawsuit (Sierra Club v. John Hankinson, et al., Civil Action 1:97-cv-3683-MHS). In February 2006, EPA filed a motion with the Court for an extension of time to complete Total Maximum Daily Loads (TMDLs) in the Coastal Streams Basin, to allow EPA and MDEQ to address the significant impacts of Hurricane Katrina on Mississippi coastal waters. On February 28, 2006, the Court granted the motion, providing that EPA shall have up to June 30, 2007 to propose TMDLs for evaluated waters in the Coastal Basin as required by Paragraph V. of the Consent Decree.

The report contains one or more TMDLs for a water body segment found on Mississippi's 1996 Section 303(d) List of Impaired Water bodies in the Coastal Streams Basin. Because of the accelerated schedule required by the consent decree, many of these TMDLs have been prepared out of sequence with the State's rotating basin approach. Implementation of the TMDLs will be prioritized within Mississippi's rotating basin approach. The amount and quality of the data on which this report is based are limited. As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, or changes in landuse within the watershed.

Conversion Factors

To convert from	To	Multiply by	To convert from	To	Multiply by
$mile^2$	acre	640	acre	ft^2	43560
km^2	acre	247.1	days	seconds	86400
m^3	ft^3	35.3	meters	feet	3.28
ft^3	gallons	7.48	ft^3	gallons	7.48
ft^3	liters	28.3	hectares	acres	2.47
cfs	gal/min	448.8	miles	meters	1609.3
cfs	MGD	0.646	tonnes	tons	1.1
m^3	gallons	264.2	µg/l * cfs	gm/day	2.45
m^3	liters	1000	µg/l * MGD	gm/day	3.79

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deka	da
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	µ	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

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ID	Name	County	HUC	Cause	Monitored/ Evaluated
MS115BCE	Bayou Caddy	Hancock	03170009	Nutrients	Evaluated
Near Lakeshore: From headwaters to mouth at Mississippi Sound					

Table ii. Water Quality Standard

Parameter	Beneficial use	Narrative Water Quality Criteria
Nutrients	Aquatic Life Support	Mississippi's current standards contain a narrative criteria that can be applied to nutrients which states: "*Waters shall be free from materials attributable to municipal, industrial, agricultural, or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use* (MDEQ, 2003)."

Table iii. Total Maximum Daily Load

Nutrient	WLA (lbs/day)	LA (lbs/day)	MOS	TMDL (lbs/day)
TP	0.0	2.59	implicit	2.59
TN	0.0	12.96	implicit	12.96

EXECUTIVE SUMMARY

Bayou Caddy (MS115BCE) is on the Mississippi 2006 Section 303(d) List of Water Bodies as an evaluated water body that is impaired due to nutrients (MDEQ, 2006). An evaluated waterbody is one that was listed based on field surveys of visible conditions and other information. Water quality monitoring data are limited or unavailable.

This TMDL addresses the nutrient impairment and provides an estimate of the total nitrogen (TN) and total phosphorus (TP) loadings in the stream for existing and TMDL conditions. Mississippi does not have numeric water quality criteria for allowable nutrient concentrations. The Mississippi Department of Environmental Quality (MDEQ) currently has a Nutrient Task Force (NTF) working on the development of criteria for nutrients and is progressing according to the State's Nutrient Criteria Development Plan, which has been mutually agreed upon by EPA and the State. This TMDL may be revised after the development of numeric nutrient criteria by the NTF.

The water body included in this TMDL is located within United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 03170009. HUC 03170009 is located in Hancock County and in the Coastal Streams Basin in Mississippi.

Average annual loads of nutrients were estimated using a spreadsheet based on EPA's Simple Method formula from the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) Pollutant Loading (PLOAD) model (USEPA, 2001). The PLOAD model was used to estimate existing nutrient loadings to the estuary based on 1992 land use conditions and to predict allowable loadings based on least disturbed conditions. The loadings resulting from the least disturbed condition represent the TMDL. The 1992 land use data were used in the analyses, as two major hurricanes in 2005 caused extensive damage to the existing watershed landscape. Best professional judgment indicates the 1992 land cover is more representative of existing conditions.

For purposes of representing least disturbed or "natural" conditions for the Bayou Caddy watershed, existing "disturbed" land uses were changed to wetlands and forest. Disturbed lands were assumed to be all land use categories with the exception of forests, water and wetlands. The percent reductions in pollutant loadings necessary to achieve "natural" conditions were calculated by subtracting the TMDL load from the existing load and dividing the difference by the existing load.

The TMDL for TN is 12.96 lbs/day, and the TMDL for TP is 2.59 lbs/day. This TMDL report recommends that the Bayou Caddy watershed be considered a priority watershed for wetlands restoration, riparian buffer zone restoration and any nutrient reduction BMPs. The implementation of these BMP activities should reduce the nutrient loads entering Bayou Caddy. This will provide improved water quality for the support of aquatic life in Bayou Caddy and will result in the attainment of the applicable water quality standards.

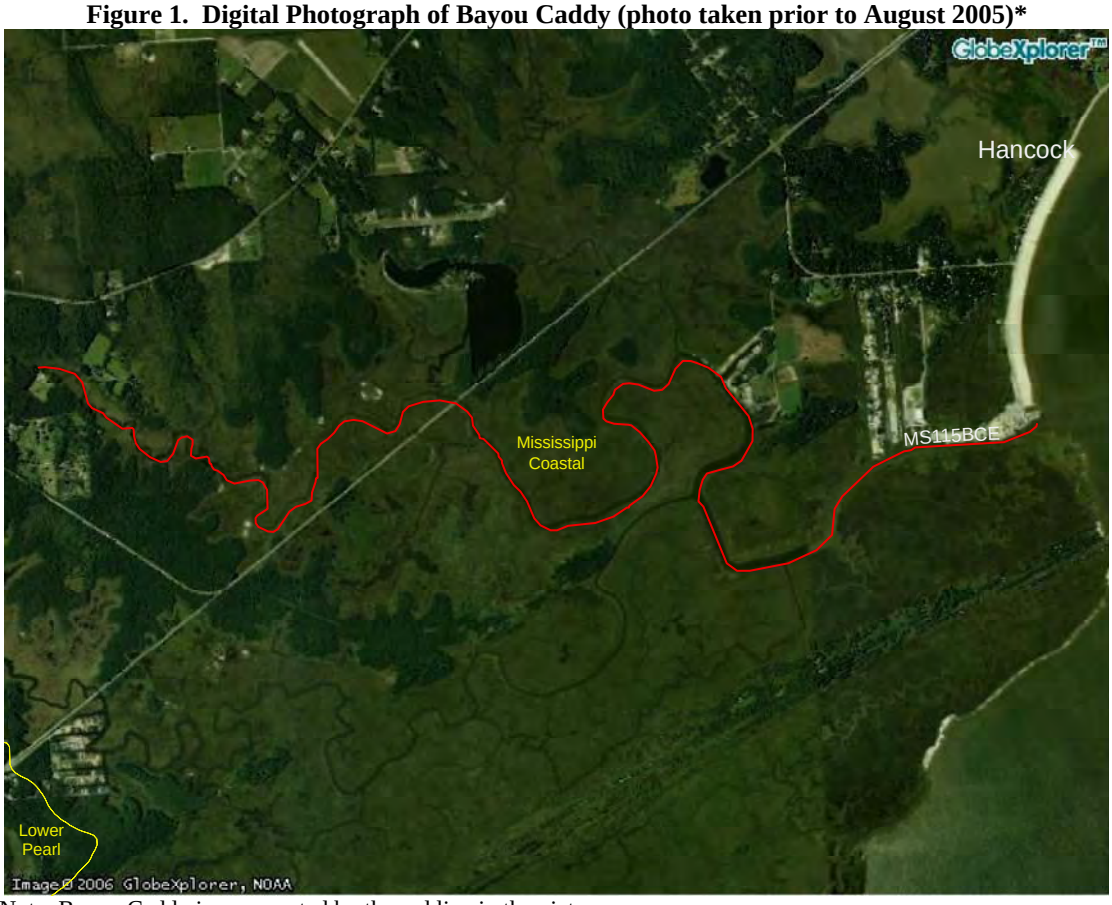
1.0 INTRODUCTION

1.1 Background

The identification of water bodies not meeting their designated use and the development of Total Maximum Daily Loads (TMDLs) for those water bodies are required by Section 303(d) of the Clean Water Act (CWA) and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to restore and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. The pollutant of concern for this TMDL is nutrients.

Bayou Caddy is within United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 03170009. The Bayou Caddy watershed is located in Hancock County (Figure 2) in Mississippi's Coastal Streams Basin. The entire watershed is 7,535.34 acres and contains many landuse types including forest, pastureland, and wetland areas. However, the dominant landuse within the watershed is wetlands. The location of the § 303(d) listed segment is shown in Figure 3.

Figure 1. Digital Photograph of Bayou Caddy (photo taken prior to August 2005)*



* Note: Bayou Caddy is represented by the red line in the picture.

Figure 2. Location of the Bayou Caddy Watershed (map provided by MDEQ)

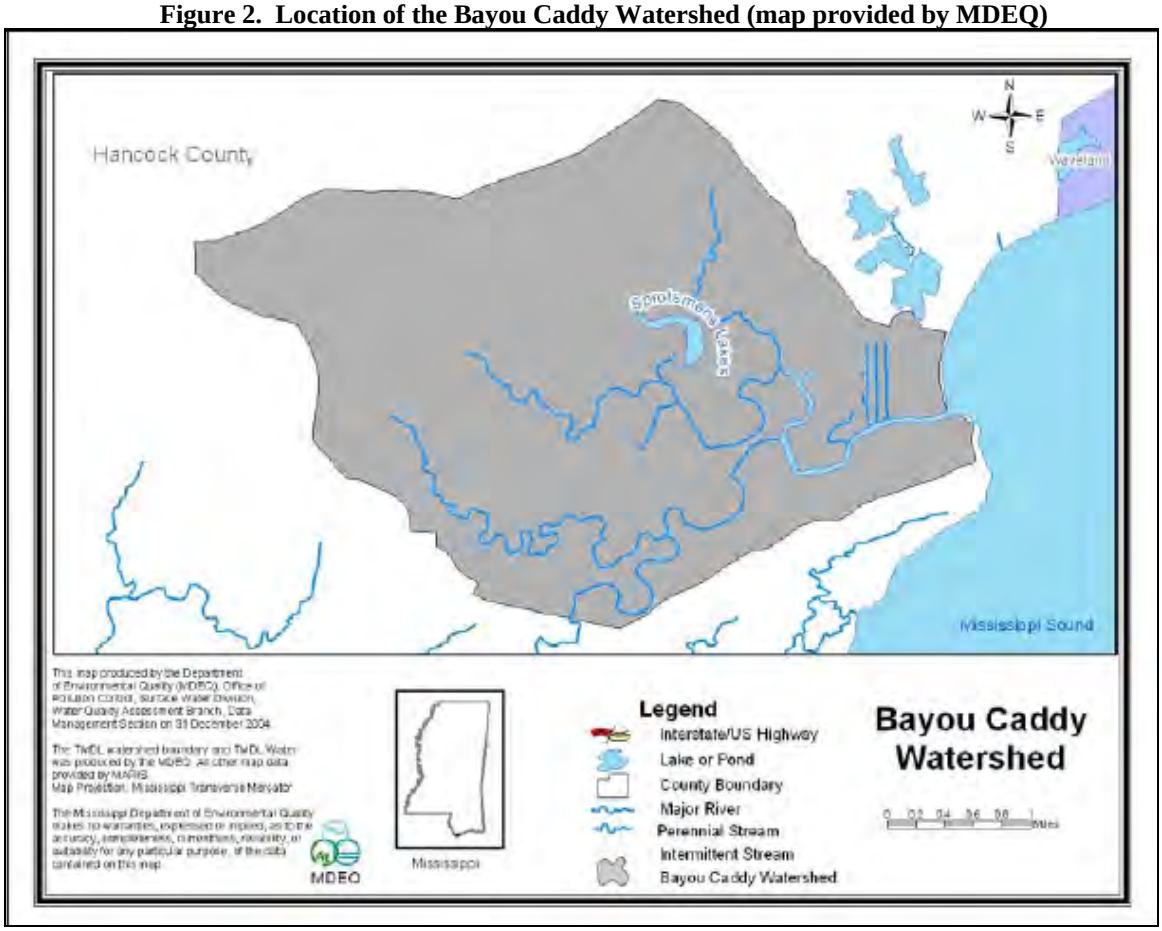
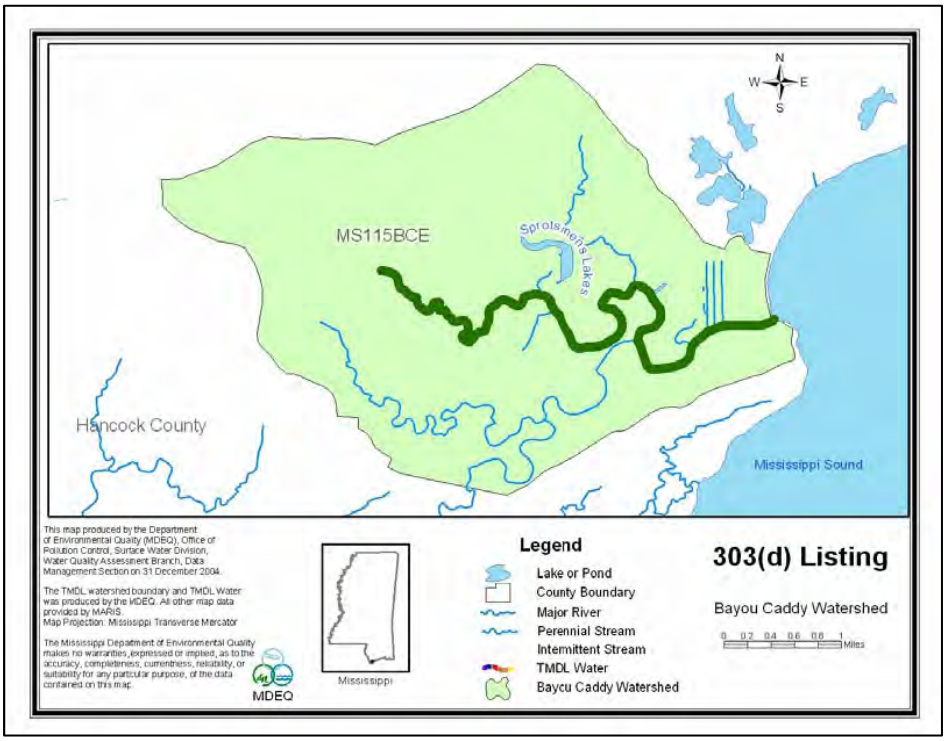


Figure 3. Bayou Caddy Watershed 303 (d) Listed Segment (map provided by MDEQ)



1.2 Applicable Water Body Segment Use

The water use classification for the listed segment of Bayou Caddy, as established by the State of Mississippi in the *Water Quality Criteria for Intrastate, Interstate, and Coastal Waters* regulation, is Fish and Wildlife Support (MDEQ, 2002b). Waters with this classification are intended for fishing and propagation of fish, aquatic life, and wildlife. Waters that meet the Fish and Wildlife Support criteria should also be suitable for secondary contact recreation. Secondary contact recreation is defined as incidental contact with the water during activities such as wading, fishing and boating, that are not likely to result in full body immersion.

1.3 Applicable Water Body Segment Standard

The water quality standard applicable to the use of the water body and the pollutant of concern is defined in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters* (MDEQ, 2003).

Mississippi's current standards contain a narrative criteria that can be applied to nutrients which states: "*Waters shall be free from materials attributable to municipal, industrial, agricultural, or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use* (MDEQ, 2002)." In the 1999 Protocol for Developing Nutrient TMDLs, EPA suggests several methods for the development of numeric criteria for nutrients (USEPA, 1999). In accordance with the 1999 Protocol, "The target value for the chosen indicator can be based on: comparison to similar but unimpaired waters; user surveys; empirical data summarized in classification systems; literature values; or professional judgment." Mississippi Department of Environmental Quality (MDEQ) uses a methodology that compares similar but unimpaired waters within the same region. This method is dependent on adequate data collection in accordance with the EPA approved plan developed with the State. The initial phase of the data collection process for wadeable streams in Mississippi is complete.

1.4 Pollutants of Concern: Total Nitrogen and Total Phosphorus

The following is an adaptation of the State of Washington Department of Ecology's *Citizen's Guide to Understanding and Monitoring in Streams and Lakes* and provides a brief description and basic understanding of the pollutants of concern for this TMDL report.

Increased nutrient concentrations are almost always an impact of pollution. Municipal and industrial discharges usually contain nutrients, and overland flow from developed watersheds contains nutrients from lawn and garden fertilizers as well as the additional organic debris so easily washed from urban surfaces. Agricultural areas also contribute to nutrient increases through poor manure and fertilizing practices and increased erosion from plowed surfaces.

Nutrient loading can typically result in increased algae growth. In flowing stream segments where conditions are right, algae take the form of an attached growth – called periphyton –on rocks, logs, and other substrate. Phytoplankton growth is also a concern in slower flowing streams. Excessive growths of algae can result in exaggerated fluctuations of normal dissolved oxygen cycles and eventually create a dissolved oxygen crash. In addition, unsightly conditions, odors, and poor habitat conditions for aquatic organisms can also be attributed to excessive algae (WDOE, 1994).

The nutrient dynamics in the estuarine system greatly differs from the nutrient dynamics in inland water bodies, which was described above. In U.S. coastal waters, nutrient over-enrichment is a common thread that ties together a diverse suite of coastal problems such as red tides, fish kills, some marine mammal deaths, outbreaks of shellfish poisonings, loss of seagrass and bottom shellfish habitats, coral reef destruction, and hypoxia and anoxia now experienced as the Gulf of Mexico's "dead zone" (NRC 2000, Rabalais et al. 1991 taken from EPA, 2001).

Phosphorus and nitrogen are the most common nutrients of concern in surface waters. Both elements are commonly measured in several forms. Phosphorus can be reported as total phosphorus (TP), which includes a particulate form and soluble reactive phosphate (SRP) (also sometimes called phosphate (PO_4^{-3}) or orthophosphate (ortho-P). The latter two are different terms used to describe the fraction of TP that is soluble, and therefore more immediately available to organisms for growth.

Nitrogen can be measured as total nitrogen (TN), total Kjeldahl nitrogen (TKN), nitrite-nitrogen (NO_2^-), nitrate-nitrogen (NO_3^-), or ammonia-nitrogen (NH_3 or NH_4^+) [NO_2^- is usually measured as nitrate-nitrite-nitrogen ($NO_3^- – NO_2^-$)]. As is the case with TP, there are fractions of TN that are more bioavailable. TKN includes the organic form of TN, which is less bioavailable for growth versus the more readily available component of TKN, which is NH_3 or NH_4^+. The fractions of NO_2^--NO_3^- and NH_3 or NH_4^+ represent forms of nitrogen that are more immediately available for growth.

Organically bound TP and TN, while not immediately available, can be converted to bioavailable forms at predictable rates; and may be significant drivers of primary productivity. One chemical form of an element can be converted into another, and the conditions under which the conversion occurs are influenced by many factors; such as pH, temperature, oxygen concentration, and biological activity. The original form of the nutrient and physical conditions will determine if an increase in total nutrient concentrations will result in higher available nutrient concentrations and therefore, a corresponding immediate increase in growth or productivity. If nutrients enter as organic matter that first needs to be decomposed before it can be utilized for growth, temperature becomes important due to its effect on the rate of decomposition. During warmer months, nutrients entering the system as intact organic matter would be decomposed relatively quickly as compared to cold, wet-weather months when decomposition is slower. These dynamics are further complicated by the fact that increased growth leads to greater numbers of organisms that need even more nutrients. So, as nutrients become available they are immediately utilized.

1.5 Nutrient Target Development

MDEQ has two approaches for deriving nutrient targets for coastal and inland streams. The approach for deriving nutrient targets for coastal streams is considered preliminary, as the targets have not been adopted by MDEQ at the time of this TMDL. In lieu of numerical WQS for nutrients, EPA has based the allocations established in this TMDL on concentrations derived from the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) Pollutant Loading (PLOAD) model (USEPA, 2001). Nutrient concentrations derived from the PLOAD model are considered conservative and contribute to the implicit Margin of Safety for this TMDL. MDEQ's approach for deriving nutrient targets for inland streams is described in Section 1.5.2, and although not applicable to coastal streams, is provided in this report for reference purposes only.

1.5.1 Coastal Stream Targets

Bayou Caddy is a tidally influenced estuarine stream. MDEQ is working with a contractor, FTN & Associates, Ltd. to develop nutrient criteria for estuaries and coastal waters. FTN conducted an extensive literature search on the effects of nutrients on estuarine systems and used existing water quality data for some of Mississippi's coastal estuaries to develop preliminary nutrient thresholds for water bodies in the Coastal Streams Basin. FTN's review of nutrient concentrations reported in the literature suggest TMDL thresholds for coastal streams converge to TN and TP concentrations of 1.5 mg/L and 0.1 mg/L, respectively (MDEQ, 2007). Several coastal streams are scheduled for TMDLs in the future and nutrient targets derived from FTN's efforts and adopted by MDEQ will be used along with flow data to develop load allocations for impaired coastal streams.

Flow data are not available for Bayou Caddy; therefore, EPA is using the Simple Method formula from the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) Pollutant Loading (PLOAD) model (USEPA, 2001) to determine the appropriate TN and TP targets for the Bayou Caddy watershed. PLOAD model results suggest TN and TP target concentrations 1.0 and 0.2 mg/L, respectively. These concentrations are in the range of values cited in the FTN literature review. Additional details on the PLOAD model are included in Section 3.0.

1.5.2 Nutrient Targets for Inland Streams

Nutrient targets for inland streams are based on data collected quarterly at 99 discrete sampling stations state wide where biological data already existed. These stations were identified and used to represent a range of stream reaches according to biological health status, geographic location (selected to account for ecoregion, bioregion, basin and geologic variability) and streams that potentially receive nonpoint source pollution from urban, agricultural, and silviculture lands as well as point source pollution from NPDES permitted facilities.

Nutrient concentration data were not normally distributed; therefore, data were log transformed for statistical analyses. Data were evaluated for distinct patterns of various data groupings (stratification) according to natural variability. Only stations that were

characterized as "least disturbed" through a defined process in the M-BISQ process (M-BISQ 2003) or stations that resulted in a biological impairment rating of "fully attaining" were used to evaluate natural variability of the data set.

The M-BISQ, a regionally calibrated benthic index of biotic integrity, was developed through a partnership between MDEQ and Tetra Tech, Inc. in 2001 from 434 wadeable (perennial, 1st-4th order streams) in the state excluding the Yazoo Delta. This index defined five bioregions for the state, and established the 25th percentile of the least disturbed condition for each bioregion as the threshold of impairment of the state of Mississippi's wadeable streams.

Each of these two groups was evaluated separately ("least disturbed sites" and "fully attaining sites). Some stations were used in both sets, in other words, they were considered "least disturbed" and "fully attaining". The number of stations considered "least disturbed" was 30 of 99, and the number of stations considered "fully attaining" was 53 of 99.

Several analysis techniques were used to evaluate nutrient data. Graphical analyses were used as the primary evaluation tool. Specific analyses used included; scatter plots, box plots, Pearson's correlation, and general descriptive statistics.

In general, natural nutrient variability was not apparent based on box plot analyses according to the four stratification scenarios. MDEQ initially selected bioregions as the stratification scheme to use for TMDL targets in the Pascagoula Basin. However, this was not appropriate for some water bodies in smaller bioregions. Therefore, MDEQ now uses ecoregions as a stratification scheme for streams in the remainder of the state.

In order to use the data set to determine possible nutrient thresholds, nutrient concentrations were evaluated as to their correlation with biological metrics. MDEQ completed this thorough evaluation prior to the Pascagoula River Basin TMDLs. Once the methodology and approach were verified, it was then applied to other ecoregions.

Data collected at each of the nutrient sites were reduced to station means. The station means from all nutrient sites in that ecoregion that are fully supporting the aquatic life use support according to the M-BISQ scores were used to calculate the 75th percentile concentrations. The 75th percentile concentration was selected as the target nutrient concentration for inland streams. The median concentration of data collected from sites not attaining WQS and those sites that had nutrient concentrations greater than the target were used to estimate existing conditions for inland steams.

2.0 TMDL ENDPOINT AND SOURCE ASSESSMENT

2.1 Selection of a TMDL Endpoint

One of the major components of a TMDL is the establishment of target endpoints, which are used to evaluate the attainment of WQS. Target endpoints, therefore, represent the water quality goals that are to be achieved by meeting the load and wasteload allocations specified in the TMDL. The endpoints allow for a comparison between observed conditions and future conditions that are expected to restore designated uses. The TMDL enpoints for Bayou Caddy are TN and TP concentrations of 1.0 and 0.2 mg/L, respectively.

2.2 Source Assessment and Load Estimation

An important part of the TMDL analysis is the identification of individual sources, source categories, or source subcategories of nutrients in the watershed and the amount of pollutant loading contributed by each of these sources. Under the CWA, sources are broadly classified as either point or nonpoint sources. Under 40 CFR **§** 122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges.

2.3 Assessment of Point Sources

A wasteload allocation (WLA) is given to all NPDES facilities in the watershed permitted to discharge to surface waters. Under the NPDES program, permitted facilities may authorize a discharge only if the applicant provides reasonable assurance that the discharge will not cause or contribute to violations of the water quality criteria. There are no municipal wastewater or industrial NPDES facilities in the Bayou Caddy watershed permitted to discharge to surface waters.

Municipal Separate Storm Sewer Systems (MS4s) may also discharge to waterbodies in response to storm events. Large and medium MS4s serving populations greater than 100,000 people are required to obtain a NPDES storm water permit under the Phase I storm water regulations. After March 2003, small MS4s serving urbanized areas were required to obtain a permit under the Phase II storm water regulations. An urbanized area is defined as an entity with a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile. There are no municipalities in the watershed of sufficient population or density requiring MS4 permits.

2.4 Assessment of Nonpoint Sources

Total nitrogen is a combination of many forms of nitrogen found in the environment. Inorganic nitrogen can be transported in particulate and dissolved phases in surface runoff. Dissolved inorganic nitrogen can be transported in groundwater and may enter a stream from groundwater infiltration. In agricultural areas, studies have indicated that human activities have increased nitrate concentrations in ground water. In urban areas, it is likely that nitrogen sources are relatively localized when compared with the generally more intensive and widespread use of fertilizers on cropland. The greater the percentage

of impervious surfaces in a watershed (usually more predominant in urban areas) generally results in surface runoff of nutrient-laden water, rather than seepage to ground water (USGS, 1999). Finally, atmospheric gaseous nitrogen may enter a stream from atmospheric deposition.

Unlike nitrogen, phosphorus is primarily transported in surface runoff when it has been sorbed by eroding sediment. Phosphorus may also be associated with fine-grained particulate matter in the atmosphere and can enter streams as a result of dry fallout and rainfall (USEPA, 1999). However, phosphorus is typically not readily available from the atmosphere or the natural water supply (Davis and Cornwell, 1988). As a result, phosphorus may be a limiting nutrient in nonpoint source dominated rivers and streams, with the exception of watersheds which are dominated by agriculture and have high concentrations of phosphorus contained in the surface runoff due to fertilizers and animal excrement or watersheds with naturally occurring soils which are rich in phosphorus (Thomann and Mueller, 1987). Table 1 presents an estimate of typical nutrient loading ranges associated with various land uses.

Table 1. Nutrient Loadings for Various Land Uses

Landuse	Total Phosphorus [lb/acre-y]			Total Nitrogen [lb/acre-y]		
	Minimum	Maximum	Median	Minimum	Maximum	Median
Roadway	0.53	1.34	0.98	1.2	3.1	2.1
Commercial	0.61	0.81	0.71	1.4	7.8	4.6
Single Family-Low Density	0.41	0.57	0.49	2.9	4.2	3.6
Single Family-High Density	0.48	0.68	0.58	3.6	5.0	5.2
Multifamily Residential	0.53	0.72	0.62	4.2	5.9	5.0
Forest	0.09	0.12	0.10	1.0	2.5	1.8
Grass	0.01	0.22	0.12	1.1	6.3	3.7
Pasture	0.01	0.22	0.12	1.1	6.3	3.7

Source: Horner et al., 1994 in Protocol for Developing Nutrient TMDLs (USEPA 1999)

The 7,535.34 acre drainage area of the Bayou Caddy watershed contains many different landuse types, including forest, cropland, pasture, barren, and wetlands, as shown in Table 2 and Figure 3. The dominant landuse within the watershed is wetlands. The landuse information for the watershed is based on the National Landcover Dataset (NLCD), which is based on digital images taken between 1992 and 1993.

Table 2. Bayou Caddy Watershed Landuse Distribution based on NLCD Dataset

	Urban	Forest	Cropland	Pasture/Grass	Transitional	Water/Wetland	Total
Acres	15	2677	266	1309	210	3058	7535
Percentage	0.2%	35.6%	3.5%	17.4%	2.9%	40.6%	100.0%

2.5 Effects of Hurricanes Katrina and Rita

Hurricane Katrina and Hurricane Rita struck the U.S. Gulf Coast on August 29, and September 24, 2005, respectively. U.S. Geological Survey (USGS) real-time instruments in Gautier, Mississippi recorded wind speeds up to 140 miles per hour and rainfall totals of approximately two feet (USEPA, October 2005). Tidal surges in nearby Bayou

Casotte were reported to be as high as 20 feet during Hurricane Katrina. The land on the Mississippi coast was cleared of most vegetation and structures due to the storm surge and wind gusts. A site assessment of Bayou Caddy has not been conducted post Hurricanes Katrina and Rita. Therefore, it is difficult to accurately qualify the rate and extent to which the land use types (e.g., wetlands, forest) that comprise Bayou Caddy have recovered. Best professional judgment suggests that most of the land use types would have reverted back to wetlands and that existing wetlands impacted by the hurricanes will recover over time. Re-development efforts in Hancock County are underway. Efforts are being made to protect existing marshlands and greenways in the watershed as redevelopment continues along the Mississippi coastline.

3.0 ANALYTICAL APPROACH

3.1 Background

Average annual loads of nutrients were estimated using a spreadsheet based on EPA's Simple Method formula from the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) Pollutant Loading (PLOAD) model (USEPA, 2001):

$$LP = \Sigma u\ (P * PJ * RVu * Cu * Au * 2.72 / 12)$$

Where: LP = Pollutant load, lbs
P = Precipitation, inches/year
PJ = Ratio of storms producing runoff (default = 0.9)
RVu= Runoff Coefficient for land use type u, inches of runoff/inches of rain
RVu=0.05 + (0.009 * Iu); Iu = percent imperviousness
Cu = Event Mean Concentration for land use type u, milligrams/liter
Au = Area of land use type u, acres.

3.2 Nutrient Loadings

The PLOAD model was used to estimate nutrient loadings to the estuary based on existing land use conditions and least disturbed conditions. Loadings resulting from the least disturbed condition represent the TMDL. Given the impacts of the hurricanes on the water body and watershed, EPA is using the 1992 NLCD dataset to reflect the land use conditions in Bayou Caddy that may have existed pre-hurricanes.

The PLOAD model uses average annual rainfall and event mean concentrations (EMCs) to estimate average annual pollutant loading transported off a particular land use. The EMC values are the measure of pollutant levels during a runoff event, and are expressed as the loadings for specific constituents divided by the stormwater volume in the runoff event. The model assumes all lands are connected to the stream, resulting in a conservative estimate of average annual loads. An annual average rainfall of approximately 60.5 inches was assumed to fall on the impaired watershed, and this is

based on meteorological data collected by Hancock County, Mississippi. The default ratio of 0.9 for storms producing runoff was assumed in the model. Land use data entered into the spreadsheet for existing conditions were based on the 1992 land use/cover features categorized according to the National Land Cover Data (NLCD) (see Table 2). EMC values assumed for the various land uses are default values contained in the BASINS PLOAD model (USEPA, 2001). Average annual loads resulting from the PLOAD model are converted to daily loads by dividing model results by 365 days per year.

For the TMDL analysis, existing "disturbed" land uses were changed to wetlands and forest for purposes of representing least disturbed or "natural" conditions for the Bayou Caddy watershed. In the analysis disturbed lands were assumed to be all land use categories with the exception of forests, water and wetlands. Model results for existing and TMDL "unimpacted" conditions are shown in Table 3. The percent reductions in pollutant loadings necessary to achieve "natural" conditions were calculated using the following equation:

Percent Reduction = (existing load – TMDL load)/existing load * 100

Table 3. Overall Percent Reductions Required to Achieve "Unimpacted" landuse conditions

Condition	**Total Annual Load (lbs/year)**	
	TN	**TP**
Existing	4821	973
Least Disturbed	4732	946
Percent Reduction	2%	3%

4.0 DEVELOPMENT OF THE TMDL

4.1 Introduction

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable WQS based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (WLA), nonpoint source loads (LA), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality. Conceptually, this definition is represented by the equation:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and WQS achieved. According to 40 CFR §130.2 (i), TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or other appropriate measures. TMDLs for Bayou Caddy are expressed as daily loads and the percent reduction of the estimated existing loads required for Bayou Caddy to achieve WQS.

4.2 Wasteload Allocation

There are no point sources that are currently discharging into Bayou Caddy. Therefore, the waste load allocations for TP and TN have been set to zero. This TMDL would need to be revised to allow for any additional allocations for future point sources prior to the issuance of NPDES permits.

4.3 Load Allocation

Best management practices (BMPs) should be encouraged in the watershed to reduce potential TN and TP loads from nonpoint sources. The watershed should be considered a priority for wetlands restoration, riparian buffer zone restoration and any nutrient reduction BMPs. Nutrients are typically transported to streams by sediment; therefore, for land disturbing activities related to silviculture, construction, and agriculture, it is recommended that practices, as outlined in 'Mississippi's BMPs: Best Management Practices for Forestry in Mississippi" (MFC, 2000), "Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater" (MDEQ, et. al, 1994), and "Field Office Technical Guide" (NRCS, 2000), be followed, respectively.

4.4 Critical Conditions

The critical condition for nonpoint source loadings is typically an extended dry period followed by a rainfall runoff event. During the dry weather period, pollutants build up on the land surface, and are washed off by rainfall. Expression of a nutrient impairment (e.g. algal blooms) is more likely to occur during warmer months. However, because nutrients (especially phosphorus) can accumulate, nutrient loadings are usually considered over longer periods (e.g. seasonally or annual averages).

EPA was unable to cross-reference rainfall events and pollutant loadings. Therefore, critical conditions and seasonal variation were incorporated into the TMDL development by using EMCs in a National dataset in BASINS, which would be representative of the Bayou Caddy watershed. EPA used pollutant loadings during "undisturbed" conditions of wetlands and forests to determine average annual loads (expressed in daily terms by dividing by 365 days per year). Wetlands, if restored and functioning well, will provide for retention and uptake of nutrients after rainfall events and before nutrients can be flushed into Bayou Caddy. Therefore, BMPs for wetland restoration, riparian restoration and nutrient reduction will be critical to achieving the reductions called for in this TMDL.

4.5 Margin of Safety

TMDLs shall include a margin of safety (MOS) that take into account any lack of knowledge about the pollutant loading and in-stream water quality. There are two methods for incorporating a MOS in the analysis: 1) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or 2) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. An implicit MOS was used in these TMDLs by targeting background loadings based on a least disturbed land cover, and assuming all landuses are connected directly to the stream.

4.6 Determination of TMDL Components

The TMDL components are expressed as daily loadings of TN and TP calculated from average annual loadings estimated from the PLOAD model. The TMDL components for Bayou Caddy are summarized in Table 4. The percent reductions necessary to achieve the TMDL values are very low; as a small percentage of the 1992 landuse is classified as disturbed (see Table 2). The BMPs used to implement the TMDL should result in WQS being met on a daily basis. EPA believes that the annual average loads provided in Table 3 will more effectively facilitate the implementation of the TMDL and the attainment of WQS in Bayou Caddy.

Table 4. Summary of TMDL Components

Parameter	WLA (lbs/day)	LA (lbs/day)	TMDL (lbs/day)	Percent Reduction
TN	0.0	12.96	12.96	2%
TP	0.0	2.59	2.59	3%

4.6 Seasonal Variation

Seasonal variation is considered in the TMDL to ensure that WQS will be met during all seasons of the year. Seasonal variation was considered in the analysis through the use of average annual rainfall data collected over several seasons.

5.0 CONCLUSION

The TMDL for TN is 12.96 lbs/day and the TMDL for TP is 2.59 lbs/day. It is recommended that the Bayou Caddy watershed be considered as a priority watershed for wetlands restoration, riparian buffer zone restoration and any nutrient reduction BMPs. The implementation of these BMP activities should reduce the nutrient load entering Bayou Caddy. This will provide improved water quality for the support of aquatic life in Bayou Caddy and will result in the attainment of the applicable WQS.

5.1 Public Participation

The TMDL report was proposed for public review and comment for a 30-day period. EPA notified the public by publishing a notice of the TMDL through a legal ad in the statewide newspaper, the *Clarion-Ledger*. The public notice also appeared in the local newspaper, the *Mississippi Sun Herald*. EPA also provided notice to members of the public through e-mail who have requested that MDEQ include them on a TMDL mailing list. EPA did not receive any comments on the report during the public notice period.

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DEFINITIONS

Allocations: That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Ambient Stations: A network of fixed monitoring stations established for systematic water quality sampling at regular intervals, and for uniform parametric coverage over a long-term period.

Anthropogenic: Pertains to the [environmental] influence of human activities.

Assimilative Capacity: The amount of contaminant load that can be discharged to a specific stream or river without violating the provisions of the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters and Water Quality* regulations. Assimilative capacity is the extent to which a body of water can receive wastes without significant deterioration of beneficial uses.

Background: Ambient pollutant concentrations due to natural sources, nearby sources other than the one currently under consideration, and unidentified anthropogenic sources.

Background Levels: Levels representing the chemical, physical, and biological conditions that would result from natural geomorphologic processes such as weathering or dissolution.

Best Management Practices (BMPs): (1) The methods, measures, or practices selected by an agency to meet its nonpoint source control needs. BMPs include but are not limited to structural and nonstructural controls and operation and maintenance procedures. BMPs can be applied before, during, or after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters. (2) Methods have been determined to be the most effective, practical means of preventing or reducing pollution from nonpoint sources.

Critical Condition: The critical condition can be thought of as the "worst case" scenario of environmental conditions in the water body in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.

Cross-Sectional Area: Wet area of a waterbody normal to the longitudinal component of the flow.

Daily Discharge: The discharge of a pollutant measured during a 24-hour period that reasonably represents the day for purposes of sampling. For pollutants with limitations expressed in units of mass, the daily discharge is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurement, the daily discharge is calculated as the average measurement of the pollutant over the day.

Designated Use: (1) Those uses specified in water quality standards for each water body or segment whether or not they are being attained. (2) Those water uses identified in state water quality standards which must be achieved and maintained as required under the Clean Water Act.

Discharge Monitoring Report: Report of effluent characteristics submitted by a NPDES permitted facility.

Ecoregion: A physical region that is defined by its ecology, which includes meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Effluent: (1) Any solid, liquid, or gas which enters the environment as a by-product of a man-oriented process. The substances that flow out of a designated source. Effluent, effluence, and efflux have the same

meaning. (2) Wastewater – treated or untreated – that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

Effluent Standards and Limitations: All State or Federal effluent standards and limitations on quantities, rates, and concentrations of chemical, physical, biological, and other constituents to which a waste or wastewater discharge may be subject under the Federal Act or the State law. This includes, but is not limited to, effluent limitations, standards of performance, toxic effluent standards and prohibitions, pretreatment standards, and schedules of compliance.

Impaired Water body: Any water body that does not attain water quality standards due to an individual pollutant, multiple pollutants, pollution, or an unknown cause of impairment.

Surface Runoff: Precipitation, snow melt, or irrigation in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter or nonpoint source pollutants.

Load Allocation (LA): The portion of a receiving water's loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished.

Loading: The portion of a receiving water's loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished.

NPDES Permit: An individual or general permit issued by the MDEQ Permit Board pursuant to regulations adopted by the Commission under Mississippi Code Annotated (as amended) § 49-17-17 and § 49-17-29 for discharges into State waters.

Narrative Criteria: Nonquantitative guidelines that describe the desired water quality goals.

Natural Waters: Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.

Nonpoint Source: The pollution from sources which generally are not controlled by establishing effluent limitations under sections 301, 302, and 402. Nonpoint source pollutants are not traceable to a discrete identifiable origin, but generally result from land runoff, precipitation, drainage, or seepage. This water may contain pollutants that come from land use activities such as agriculture, construction, silviculture, surface mining, disposal of wastewater, hydrologic modifications, and urban development.

Numeric Target: A measurable value determined for the pollutant of concern which, if achieved, is expected to result in the attainment of water quality standards in the listed water body.

Phased Approach: Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.

Point Source: Pollution from a stationary location or fixed facility from which pollutants are discharged or emitted. Pollution from any single identifiable source, e.g., a pipe, ditch, ship, ore pit, or factory smokestack.

Pollutant: Includes, but not limited to, any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may be reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring; except that the term pollutant or contaminant shall not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of paragraph (14) and shall not include natural gas, liquefied natural gas, or synthetic gas of pipeline quality (or mixtures of natural gas and such synthetic gas).

Pollution: Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as man-made or man-induced alteration of the physical, biological, and radiological integrity of water. Other pollution related terms include: agricultural pollution, air pollution, indoor air pollution, industrial waste pollution, manmade air pollution, natural pollution, noise pollution, oil pollution, sewage pollution, soil pollution, thermal pollution, water pollution, and wood burning stove pollution.

Reference Sites: Water bodies that are representative of the characteristics of the region and subject to minimal human disturbance.

Stream Restoration: Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream due to urbanization, farming, or other disturbance.

Surface Runoff: Precipitation, snow melt, or irrigation in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter or nonpoint source pollutants.

Total Maximum Daily Load or TMDL: (1) The total allowable pollutant load to a receiving water such that any additional loading will produce a violation of water quality standards. (2) The sum of the individual waste load allocations and load allocations. A margin of safety is included with the two types of allocations so that any additional loading, regardless of source, would not produce a violation of water quality standards.

Wasteload Allocation (WLA): (1) The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality based effluent limitation. (2) The portion of a receiving water's total maximum daily load that is allocated to one of its existing or future point sources of pollution. (3) The maximum load of pollutants each discharger of waste is allowed to release into a particular waterway. Discharge limits are usually required for each specific water quality criterion being, or expected to be, violated. The portion of a stream's total assimilative capacity assigned to an individual discharge.

Water Quality Criteria: Specific levels of water quality which, if reached, are expected to render a body of water suitable for its designated use. The criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes. Water quality criteria are comprised of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

Water Quality Standards: (1) Provisions of State or Federal law which consist of a designated use or uses for the water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. (2) A law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an antidegradation statement. (3) State-adopted and EPA-approved ambient

standards for water bodies. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses.

Waters of the State: All waters within the jurisdiction of this State, including all streams, lakes, ponds, wetlands, impounding reservoirs, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, situated wholly or partly within or bordering upon the State, and such coastal waters as are within the jurisdiction of the State, except lakes, ponds, or other surface waters which are wholly landlocked and privately owned, and which are not regulated under the Federal Clean Water Act (33 U.S.C.1251 et seq.).

Watershed: (1) The land area that drains (contributes runoff) into a stream. (2) The land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common delivery point.

ABBREVIATIONS

ARS	Agricultural Research Service
BMP	Best Management Practice
CWA	Clean Water Act
CWPRU	Channel and Watershed Processes Research Unit
EPA	Environmental Protection Agency
HUC	Hydrologic Unit Code
LA	Load Allocation
MARIS	Mississippi Automated Resource Information Service
MDEQ	Mississippi Department of Environmental Quality
MFC	Mississippi Forestry Commission
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resource Conservation Service
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WLA	Wasteload Allocation
WWTP	Wastewater Treatment Plant